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Research report

Acute stress affects free recall and recognition of pictures differently depending on age and sex

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HIGHLIGHTS

- Acute stress has effects on memory retrieval in mixed-sex samples of different ages.
- Older people showed a lower stress-induced cortisol response than young people.
- Pictures from the IAPS were used to study the stress effects on memory retrieval.
- Stress impaired free recall of emotional and neutral pictures only in young men.
- Stress impaired recognition memory for positive pictures in all participants.

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ABSTRACT

Little is known about age differences in the effects of stress on memory retrieval. Our aim was to perform an in-depth examination of acute psychosocial stress effects on memory retrieval, depending on age and sex. For this purpose, data from 52 older subjects (27 men and 25 women) were reanalyzed along with data from a novel group of 50 young subjects (26 men and 24 women). Participants were exposed to an acute psychosocial stress task (Trier Social Stress Test) or a control task. After the experimental manipulation, the retrieval of positive, negative and neutral pictures learned the previous day was tested. As expected, there was a significant response to the exposure to the stress task, but the older participants had a lower cortisol response to TSST than the younger ones. Stress impaired free recall of emotional (positive and negative) and neutral pictures only in the group of young men. Also in this group, correlation analyses showed a marginally significant association between cortisol and free recall. However, exploratory analyses revealed only a negative relationship between the stress-induced cortisol response and free recall of negative pictures. Moreover, stress impaired recognition memory of positive pictures in all participants, although this effect was not related to the cortisol or alpha-amylase response. These results indicate that both age and sex are critical factors in acute stress effects on specific aspects of long-term memory retrieval of emotional and neutral material. They also point out that more research is needed to better understand their specific role.

1. Introduction

A large body of research in animals and humans shows that stress affects memory. Stress involves the release of glucocorticoids (corticosterone in rodents, cortisol in humans) and catecholamines due to the activation of the hypothalamus–pituitary–adrenal axis (HPA-axis) and the sympathetic nervous system (SNS), respectively. While glucocorticoids can cross the blood–brain barrier and bind to receptors (i.e., mineralcorticoid and glucocorticoid receptors) located in the hippocampus, prefrontal cortex and amygdala, brain areas related to memory processes [1–3], the catecholamines

Abbreviations: HPA-axis, hypothalamus–pituitary–adrenal axis; SNS, sympathetic nervous system; TSST, Trier Social Stress Test; sAA, salivary alpha-amylase; IAPS, International Affective Picture System; SAM, Self-Assessment Manikin.

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do not have this property. Thus, the latter exert their action on memory by activating the β-adrenergic receptors on vagal afferents projecting to the nucleus of the solitary tract in the brainstem [4], and these noradrenergic projections influence the neuronal activity of the amygdala [5]. Nevertheless, memory can be enhanced, impaired or even unaffected by stress because factors such as the memory phase tested (i.e., learning, consolidation or retrieval), the emotional valence of the material to be remembered (i.e., emotional or neutral), or the age and sex of the individuals can modulate this relationship.

As found in animal studies, a pharmacologically-induced [6–9] or stress-induced [10–16] cortisol increase impairs retrieval performance in young people. The effect of stress on long-term memory (24 h at least) retrieval seems to be rather consistent because impairing effects have been observed when stress triggers high [11,13,14] and moderate [10,15,16] cortisol responses. In these studies, different types of memory tasks with different levels of difficulty have been employed, such as lists of words (with 30 words in Kuhlmann et al. [13] and Smeets [16], 80 words in Buchanan et al. [10] and 100 words in Smeets et al. [15]), pictures (20 in Buchanan and Tranel [11]) and paragraphs [14]. A few studies have shown a lack of a stress effect on long-term memory retrieval in young women in the luteal phase of the menstrual cycle [17] and when the memory retrieval was performed two or more days after learning [18,19].

One modulatory factor in the relationship between cortisol and memory seems to be the emotional valence of the material to be remembered (i.e., emotional or neutral). Emotional material induces a greater noradrenergic activation of the amygdala than neutral material, and, as has been described, the interactions between the amygdala and hippocampus are crucial in finding cortisol effects on hippocampus-dependent memory performance [3]. Thus, the majority of studies carried out in young people showed a stronger impact of cortisol or stress on memory for emotionally arousing material than for neutral material (for a review see: [20]).

Most of the studies on the effects of cortisol administration or stress-induced cortisol increases on memory have been conducted in young people. However, some age-related changes may affect the relationship between stress-induced cortisol response and memory performance in the older population. Previous studies have suggested that older people show (compared to young people) changes in the functional connectivity between the amygdala and hippocampus and decreases in amygdala activation for negative stimulus [21–24]. Thus, given that interactions between the amygdala and hippocampus seem to be essential to observe cortisol effects on hippocampus-dependent memory performance [3], this age-related change may influence the effects of stress and cortisol on long-term memory retrieval in older people. Another change that can be observed in the aging brain is a loss and/or dysfunction of mineralcorticoid and glucocorticoid receptors [25–27], which could make older people's memory less sensitive to being affected by cortisol increases [28,29].

In spite of evidence suggesting an age-related change in stress and cortisol effects on memory performance, only a few studies have been reported in older people. Previous studies investigating the effects of stress on memory in older people have mainly shown that cortisol increases before learning (i.e., without differentiating stress effects on the learning, consolidation or retrieval phases) impair memory performance [30–33]; but see [34], an effect that seems to be due to the detrimental effect of cortisol on retroactive interference in older people, but not in young adults [31]. By contrast, studies in animals and humans have shown a lack of stress and cortisol effects on working memory, spatial memory and declarative and non-declarative memory [33,35–38]. To our knowledge, only one study investigated the effects of acute stress on long-term memory retrieval in a sample of older people, finding no effects of stress [39]. However, although some previous studies have used both older and young samples to investigate the effects of cortisol increases on learning [31], and a short-time after learning [33], there are no studies that have directly compared the effects of a stress-induced cortisol increase on long-term memory retrieval in young and older people.

In order to further examine the lack of cortisol effects on long-term memory retrieval in older people found in our previous study [39], we aimed to compare them to effects in young people. To do so, we investigated the stress effects on long-term memory retrieval performance for pictures in the older sample and in a novel sample of young people. Thus, in the present study we have compared, for the first time, the effects of a stress-induced cortisol increase on long-term memory retrieval of pictures in older and young people. To this end, two age groups of participants (older and young) were exposed to the Trier Social Stress Test (TSST) or a control task. After the stress or control task, free recall and recognition of pictures learned one day before were assessed. Moreover, in order to investigate whether the emotional arousal of the memory material plays a crucial role in the acute stress effects on memory retrieval, we used positive, negative and neutral pictures. Finally, we also tested whether the participants' sex influenced the stress effects on retrieval, due to the existence of sex differences in the stress response and their effects on this type of memory. Based on the literature, we expected stress to impair long-term memory retrieval in young people [10,11,13–16], but not in older people [39]. In addition, because sex-related differences in young people have been reported [40–42], we hypothesized that there would be a stronger impairing effect in young men, due to their expected higher cortisol response to the stressor [43–45] and the protective effects of estrogen in women [46].

2. Methods

2.1. Participants

The current study is part of an extensive on-going project (Mneme Project) aimed to investigate the effects of psychosocial stress on memory performance, taking into account different moderating factors (including age and sex) through separate and consecutive studies in healthy people. Here, we studied a sample composed of 102 subjects divided into a group of older people (from 56 to 76 years of age) and a group of young people (from 18 to 27 years of age). Participants were submitted to one of two different conditions (stress or control). The older group ($N = 52$) was composed of 27 men (stress = 12, control = 15) and 25 women (stress = 13, control = 12). The young group ($N = 50$) consisted of 26 men (stress = 14, control = 12) and 24 women (stress = 12, control = 12), all undergraduate students. The older group belonged to a study program at the University for people over 55 years of age, and they had an educational level beyond high school. There were no significant differences between the two (stress vs. control) conditions on age, educational level or body mass index (BMI) ($p > 0.286$). Partial results from the older subsample have been previously reported [39]. In the current study, we added a group of young participants to the previous study in order to test whether the same experimental design would show stress effects on long-term memory retrieval of pictures in young adults.

All the participants completed a general questionnaire to check whether they met the study prerequisites. In order to obtain an optimal comparison of the two age cohorts and eliminate a number of possible confounding factors that could interfere with the aim of the study, we applied very restrictive criteria. The exclusion criteria were: smoking more than 10 cigarettes a day; alcohol or other drug abuse; dental, visual or hearing problems; presence of cardiovas-